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"Marine Biodiesel and Education Project for San Francisco Bay and Northern California"

Survey of 100 Recreational Boaters Using Biodiesel, 1994-1997

Purpose

CytoCulture monitored and interviewed 100 boat owners who have used Biodiesel in their recreational boats on the San Francisco Bay and surrounding estuaries and bays. The purpose of these interviews and record keeping over the past 3 years was to document "real world" experiences that boaters had using Biodiesel in diesel engines of their pleasure craft. The actual survey spreadsheet data are attached and the results are summarized in this report.

Data Interpretation

100 boaters who have purchased Biodiesel at CytoCulture for use in marine diesel engines were interviewed by written questionnaires and follow up telephone calls from 1994 through 1997. Since exactly 100 respondents are reported in this survey, the "raw numbers" can, for the most part, be considered representative "percentages" of the total pool of boaters interviewed. Most survey data is, therefore, presented in terms of "%" (percent) of the total 100 survey respondents interviewed. For example, 100 boaters, or 100%, used CytoCulture's Biodiesel (various manufacturer brands) in their boats prior to or during 1997.

Survey Respondents - Who are they?

The survey polled recreational boaters who have used Biodiesel obtained from CytoCulture and operated their boats with the Biodiesel in Northern California. Most (85%) continue to live in the area and operate their boats on San Francisco Bay. 10% of the boaters live in Sacramento, Santa Cruz and other areas of Northern California. 3 of the boaters now live elsewhere. One couple is cruising to Mexico now, one couple motored a schooner to Alaska in 1995, and Bryan

Peterson now lives in Iowa after completing a 2 year (1992-94), 35,000 mile expedition aboard *SUNRIDER*, a 28-ft Zodiac inflatable boat powered by 100% Biodiesel.

Most of the early respondents were "repeat customers" returning to CytoCulture to buy more Biodiesel, but 97% of the respondents were then interviewed by direct telephone calls in September and October, 1997, to get direct feed back on their experiences with Biodiesel in boats. Virtually all of the past Biodiesel customers that we could find and speak with are included in this survey, and none of the customers reporting a problem were excluded from the group of 100 respondents documented here. There are another 60 or more Biodiesel users in California and over 40 more Biodiesel users in other states, or overseas, that we have sold Biodiesel to since 1994. Approximately 5,000 gallons of Biodiesel has been sold to over 200 recreational boaters through our office, for an "average" sale of approximately 25 gallons per boater. All of these sales were made at a net loss to CytoCulture and were conducted on an experimental basis with no backing from the suppliers, the government or any outside funds.

Survey Results - Summary Table Layout

The results are reported here in the same order in which they appear in the attached "Summary of 1997 Survey of 100 Marine Biodiesel Customers in Northern California". The spreadsheet subtotals of respondent answers are organized into three sections, each representing a page of questions from the survey questionnaire or interview:

Section 1: General information including the boat owners name, telephone number and home city, along with the boat's home port, if reported differently. The year the boater started using Biodiesel is recorded, followed by information on the boat including, length, and diesel engine manufacturer. Section 1 information is found on survey pages 1-4, with a summary on page 4.

Section 2: Continues with information about the boat's engine age (by decade), horsepower rating and fuel hose type (USCG approved standard fuel hose vs. synthetic or Viton). Boaters were asked where they currently or in the past have purchased Biodiesel and the highest percentage of Biodiesel they blended with their diesel fuel. The section ends with questions about potential problems the boaters may have encountered using Biodiesel in higher percentage blends.

Section 3: Questions relate to benefits expressed by the boaters in using biodiesel in their recreational boats during the period of 1994-1997. Boaters were asked to identify the type of 5-gallon container they would prefer in the future (one-way recyclable light duty containers vs. a refillable, returnable heavy duty container requiring a deposit). Boaters were asked to indicate price "thresholds" at which they would still buy Biodiesel on a regular basis (as opposed to just trying it for the first time). Boaters were then asked to rate (3=primary, 2=secondary and 1=tertiary) reasons why they used Biodiesel in their boats (mechanical vs environmental vs aesthetic). They were then asked where they would prefer to buy biodiesel in the future (containers available at stores or fuel docks, or pumped directly into their boats). Boaters were asked to estimate the total amount of Biodiesel they had purchased to date and to indicate

whether they would volunteer to be interviewed again for some future survey. Lastly, any direct quotes, comments or suggestions were listed briefly (more details on original forms) to relate more anecdotal information about their Biodiesel experiences.

Year Started Using Biodiesel

Of the 100 boaters interviewed, the percentage of boaters that started experimenting with Biodiesel in one of the past 4 years are summarized as follows:

Year Started	%	
1994	24	(also includes those who started earlier)
1995	48	
1996	22	
1997	6	

A full three quarters of the respondents were using Biodiesel from CytoCulture during or prior to 1995. One quarter of the total survey respondents were already using Biodiesel in 1994 (true "pioneers"). Only 6 of the respondents are "new users", biodiesel customers in the same "generation" as their counterparts using Biodiesel in the Florida keys, the Chesapeake Bay and Puget Sound. The CytoCulture Marine Biodiesel experimental program was the first marketing study project in the world (self funded by CytoCulture with help from many volunteers) to distribute and evaluate the use of Marine Biodiesel in recreational boats.

As will be evident from the rest of the survey, these boaters represent a hardy bunch of experienced biodiesel users. The amount of Biodiesel they purchased ranged from 5 to 148 gallons, with an "average" purchase volume of approximately **25** gallons (five 5-gallon containers over the past 3 years).

Boat Type

97 Sailboats
3 Powerboats

97 percent of the boaters interviewed own and operate a sailboat equipped with an auxiliary diesel engine. Only 3 percent of the boaters operate power boats: one 36-ft trawler (used 110 gallons), one 26-ft work boat (ongoing demonstration) and the 28-ft Zodiac *SUNRIDER*, piloted by Bryan Peterson around the world on Biodiesel from/to San Francisco in 1992-1994. Bryan was somewhat of an exception: he went over 35,000 miles on 100% Biodiesel (18,000 gallons Biodiesel shipped by the National Biodiesel Board), with the last 100 gallons donated by CytoCulture for his final leg up the coast from Santa Cruz on September 8, 1994.

Boat Length

Recreational boats using Biodiesel in the San Francisco area ranged from 24-55 feet in length:

20-29 ft	30-39 ft	40-49ft	50+ft
11%	70%	12%	2%

The "average boat" among the 100 boats evaluated is a sailboat about 35 feet long.

Engine Manufacturer

Seven engine manufacturers were listed in the survey, with responses as follows:

Perkins	Mercedes	Westerbeke	Universal	Volvo	Yanmar	Isuzu	Other
14	1	10	11	17	22	5	18

Yanmar was the most common manufacturer, representing 22% of all the engines evaluated, followed by Volvo (17%), Perkins (14%) and Universal (11%).

From the point of view of our survey, we had good diversity and spread among over 7 popular marine diesel engines. All of them are European or Japanese manufacturers except the Universal engines in the sailboats, the Mercruiser inboard/outboard in the *SUNRIDER* and the big American diesel engines (e.g., Detroit Diesel) in the 36 ft trawler *Nokken* and the 26 foot work boat, the *Storm*.

Engine Year

As CytoCulture has emphasized to the National Biodiesel Board over the past 4 years, the typical recreational boater owns an older engine, often over 20 years old. The 100 boat engines identified were ranked by the decade in which they were built:

1970's	1980's	1990's
40	44	17

Two fifths of the engines were built in the 1970's (probably over 25 years old) and 84% of the boat engines are at least seven years old. There are clear disproportionate distributions of engine make vs. age, with the Perkins and Volvos found more often in the 1970's and with Yanmar being the most predominant of the newer engines installed in the 1990'. Yanmar, fortunately, is very proactive with Biodiesel worldwide, and was a sponsor of Bryan Peterson's SUNRIDER. Yanmar donated a pair of 37-HP diesel outboard engines that powered the Zodiac anytime there was a problem with the main propulsion system.

Yanmar engines, powered by Biodiesel, set a world record for time/distance for an outboard powered vessel when Bryan motored the *SUNRIDER* from San Francisco to Hawaii in 1992.

Within our group at CytoCulture, 3 test boats all had engines from the late 60's or early 70's.

Age is an important factor for evaluating engine performance on higher (>50%) concentrations of Biodiesel. Old fuel lines, old fuel filter seals and old fuel fill lines and gaskets at the tank are more prone to methyl ester-induced deterioration when the elastomers are older and have a higher natural rubber content than modern elastomers and hoses. New US Coast Guard approved "Grade A-1" fuel hose, for example, appears very resistant to Biodiesel (per data in this survey among newer boats, and from lab studies at CytoCulture).

Marine Diesel Engine Horsepower Rating

The predominant auxiliary sailboat engines among our respondents were light duty, lower horsepower engines with ratings under 30 HP. Only 5% were rated over 60 HP.

<20 HP	20-29 HP	30-39 HP	40-49 HP	50-59 HP	>60 HP
26	29	18	9	14	5

These lower ratings are typical of most recreational sailboats in the 20-36 foot length range. Also, newer 1990's engines tend to be lighter, more efficient high-rpm engines with lower horsepower output ratings compared to the older, heavier engines that ran at lower rpm.

Fuel Hose Type

Since we anticipated some problems with fuel hoses on older engines, we asked our respondents to indicated whether they had conventional US Coast Guard-approved fuel hoses or whether they had installed any alternative lines. 98% of the boats had conventional fuel hoses, and the few that had trouble with deterioration or leaks, replaced them with the more modern "type A-1" lines now sold at marine supply stores. In California, the fuel line most often sold today is:

"Trident Barrier Fuel Hose, USCG Approved Type A-1, SAE J1527 (2/93)"

Apparently on the market since 1993, this hose has not been a problem with boaters using even 100% biodiesel (all new engine installations in the 1990's would have similar hose). Preliminary laboratory experiments at CytoCulture confirmed this fuel line would absorb Biodiesel and swell slightly (tighter fit) after 2 months of submersion without any signs of deterioration. In field tests with a Mercedes Benz diesel car, conventional automotive fuel lines used as a return line to the tank are not affected after 2 years of exposure to hot Biodiesel (100% neat).

Only 2 respondents actually switched to industrial "synthetic" fuel lines, and one of them, a fabric coated hydraulic hose, began to get sticky after 1 year with 100% biodiesel. Not one of the

boaters tried "Viton" fuel hose (frightfully expensive, difficult to obtain) even though a National Biodiesel Board-funded study recently concluded this material was the only elastomer deemed "compatible" with neat Biodiesel. In our experience, even Viton seals on hand pumps will slightly swell and drip when used for long periods with neat Biodiesel.

In summary, boaters should be wary of possible drips or slippage of older fuel lines when using higher concentrations of Biodiesel. The new USCG-approved fuel lines, however, appear to hold up well even when 100% Biodiesel is used over long periods of time.

Current Source

All of the 100 boaters purchased most or all of their Biodiesel supply from CytoCulture directly, but since April 1997, at least 8 of the boaters were also buying their Biodiesel from fuel docks (mostly at Gas House Cove fuel dock, San Francisco, supplied by AEP, Iowa).

Percent Biodiesel Used

Early pioneers and environmental enthusiasts that started with our program in late 1993-1994 had a tendency to start using Biodiesel at concentrations higher than the more typical 20% (B-20) blend marketed today (for cost and regulatory reasons).

More than 75% of the boaters surveyed had used the biodiesel in concentrations greater than 25%, and nearly one quarter of all the respondents had been using Biodiesel at 100% (neat) at one time or another. 47% of the boaters used Biodiesel in excess of a 50% blend. Several boaters reported cleaning all the petroleum out of their tanks and never using anything but Biodiesel to power their boats (without any problems). In general, however, particularly with inconsistent supplies in the SF Bay area, most boaters have gone back to using a mid-range blend around 25-50%.

Range of Biodiesel concentrations used by boaters surveyed 1994-1997:

<20%	20-25%	26-49%	50-99%	100% (neat)
1	23	29	24	24

The one boater that uses it at 10-15% (for lubricity, odor and smoke reduction) operates a small tug boat with a large engine and consumes more fuel in a week than most sailboats do in a year. The Marine Biodiesel Program in California was specifically designed for sailboats since they use less fuel and gain more benefits per $ than large power boats. Future marketing will target small percentage Biodiesel blends in research vessels, Club launches, tour boats and ferries that burn considerable amounts of fuel in a year and generate significant emissions in high impact environments.

Any Problems with Biodiesel?

This question was by far the most important in the survey. Considering the survey spans an operational period of nearly 4 years, with a great predominance of older (10-25 year) engines, and Biodiesel concentrations usually in excess of 50%, it is remarkable how few problems were reported. A full **87%** of the boaters surveyed had "No Problems" and seemed genuinely content with the product and results. The problems reported break down as follows:

Fuel Line or fill line	Fuel filter clogging	Fuel tank sediment	Seals on Tank/Filter	Other (non-engine)	NONE
6	4	6	2	5	87

Fuel line and tank filling line problems were not a surprise (older, worn elastomers with higher natural rubber content), and, fortunately, easy to rectify. Most boaters with the fuel line / fill line deterioration problems (stickiness) had been using high concentrations of Biodiesel, and chose to replace the old fuel line and/or lower the concentration of Biodiesel they used.

Fuel filter clogging and fuel tank sediment problems are, of course, directly related to the solvent/cleaning action of the higher concentrations of Biodiesel in dirty tanks with slime. The tank sediment can be caused by corrosion of older galvanized tanks, from taking on bad diesel fuel, or, more often, from bacteria and mold growing in condensed water at the bottom of the fuel tank. The hydrocarbon-degrading bacteria and fungi will create a slime and sediment that will certainly accumulate in fuel filters, and could threaten the operation of the engine if it led to clogging of the filters or fuel lines. From personal experiences here at CytoCulture in the early days, it is imperative that Biodiesel be used at higher concentrations only in boats with clean fuel and clean tanks. On the San Francisco Bay, it is not uncommon for boats to accumulate "algae" (named for the bright red-orange appearance the microbe colonies display, not for the photosynthetic process requiring bright light in your tank). In fact, a lot of older boats in the Bay area, and elsewhere where condensation is a frequent problem in tanks, have their fuel filtered professionally to eliminate water, sediment and accumulated bacterial debris.

The sediment problem can be minimized by proper use of biocides (microbial inhibitors) and keeping fuel tanks "topped off", particularly in the winter, to avoid condensation of the moist sea air inside a cold fuel tank at night. Boats that remain idle for long periods (especially in the winter) with partially full tanks of fuel (diesel or biodiesel) are prime candidates for the sediment problem. One of our earliest "Biodiesel pioneers" operates his boat on 100% biodiesel with no biocides and has no problem with sediment, but he did start with a clean tank and he does regularly "top off" the tank to prevent moisture condensation.

Seals on filters and tank fittings were also problematic in a few cases (2) reported as leaks around the top of the filter and softening of the gasket for the tank level gauge. Both problems are easily corrected by replacing with modern synthetic polymer seals. Many of the boaters surveyed had installed modern water separator/filter assemblies (transparent) that held up well even to 100%

Biodiesel. Future research will be needed to identify specific brands and materials that appear compatible with the higher concentrations of Biodiesel, but for the immediate future, Biodiesel is being marketed for use in concentrations not to exceed 20%.

The "Other" problems cited in the survey results include:

* Lifting of paint along the inside of the boat bilges after a fuel spill
* Lifting of engine paint from spillage after fuel filter changes
* Accumulation of slime in old fuel jerry cans left nearly empty in a dock box in winter
* Damage to deck caulking (polysulfides) when Biodiesel was spilled on a teak deck
* Clogged diesel heater pump that draws fuel from the bottom of diesel fuel tank (sediment)
* Deteriorated fuel line squeeze bulb (replaced)

As described earlier, the tank sediment problems need to be addressed before trying to use higher concentrations of Biodiesel. The paint lifting problems can be avoided by mopping up spills quickly with absorbents and washing the surfaces with warm, soapy water. Traces of fuel left in empty jerry cans for a winter will lead to bacterial growth, so the jerry can should be drained completely and kept dry if possible. Deck problems and bilge problems are preventable by avoiding spills, or if they do occur, by thoroughly removing all traces of the Biodiesel with absorbent pads and washing the area with mild (biodegradable) soapy water.

Biodiesel Benefits

As anticipated, boaters responded with a variety of reasons for buying the Biodiesel and using it in relatively high concentrations, in spite of the price, or inconveniences of replacing old hoses. Most of the observed benefits cited were attributable to improved exhaust emissions or noticed improved performance of the engines at low rpm or idle:

Improved Engine Smoothness	Less Smoke	Less Soot	Better Odor	Handling Qualities	Safety
43%	91%	56%	98%	67%	88%

Decreased exhaust emissions (smoke, odor and soot reductions) clearly were noticed by most of the users, and were often cited as the principal reason to purchase Biodiesel (see below). Depending on the age and condition of the diesel engine, other factors such as soot deposits were reduced. Soot accumulation (black oily residue) on boat transoms and decks is a frequent complaint of boaters motoring home with a following wind (typical of the Bay and the River Delta areas). One family claimed the reduction in smoke and noxious fumes was enough to make them change out their fuel entirely to Biodiesel. Several respondents mentioned feeling better and enjoying their boats more even when they had to motor a lot.

Handling qualities were mostly praised by boaters having to replace their own fuel filters from time to time, or otherwise work with the fuel system and fuel up their boats themselves. Biodiesel smells better, and was reported more pleasant to work with even though it did stain clothes (dry cleaning usually removes the stain).

Safety benefits were also frequently cited among boaters who have to handle the fuel in containers, or store it aboard their boats in jerry cans as extra fuel for longer trips. Most boaters agreed it was much nicer to smell Biodiesel and know they were not smelling toxic petroleum fumes when they used Biodiesel in higher concentrations in their fuel.

Container Types

The survey asked boaters to indicate their preferences among two types of containers that will be offered for Biodiesel next spring: "one-way" light plastic containers intended for short term storage and disposal by recycling (HDPE) vs. "returnable" heavy duty containers for longer term storage in boats and exchangeable every time the boater buys more Biodiesel. The returnable container would require a deposit of $12, but that seemed not to deter those who favored this container system over the current disposable containers marketed today.

One-way containers Recycle when done	Returnable containers Exchange for Refill	None
15%	81%	4%

Price Threshold

Boaters were polled on the issue of price. Obviously, all of us want it cheaper and now. Realistically, they were told, the price of Biodiesel will drop in time as the market grows and the production can be shifted to a local plant (minimal transportation costs) converting used cooking oils (or other available local vegetable oil feed stocks) into Biodiesel.

The question raised here was: "What would be the highest price (rounded to the $) at which you would still continue to buy Biodiesel for your boat?"

$3.00 / gallon	$4.00 / gallon	Current $5.00 / gallon
6%	19%	75%

Although price is clearly an issue for many boaters (some said it was "not an issue"), it appears from this poll that the majority of the boat owners will continue to buy the Biodiesel at the current price. More often, the complaint was lack of availability and inconvenience in getting the Biodiesel rather than the price. Fortunately, this latter problem is getting resolved.

Reasons to Use Biodiesel

Since 1994, we have been asking boaters using Biodiesel to "rate" the following three reasons for why they chose to buy the Biodiesel for their boats in spite of the inconvenience or price. Each of the "reasons" was rated "3" for highest, "2" for second and "1" for lowest priority.

Accumulative (100 boaters) Rating for Highest Priority:

180 "Mechanical" reasons: Higher lubricity, smoother operation, complete combustion

220 "Environmental" reasons: Cleaner emissions, less pollution, non-toxic, biodegradable

200 "Aesthetic" reasons: Less soot, less smoke, less odor, pleasant to handle, safety

In other words, 37% of the boaters stated that "environmental" reasons were most important, 30% responded that "aesthetic" reasons were the highest priority, and 33% indicated their interest in improved "mechanical" performance of their engines (mostly for lubricity). Engine smoothness (particularly at idle) and easy starting were other important mechanical reasons cited.

It is obvious that all three reasons are nearly equal in importance when the 100 boater population is viewed as a whole. Some boaters were adamant about the environmental issues while others never considered the emissions improvements, they just wanted their engines to run better and get better lubricity to protect their expensive fuel pumps. In the end, all three reasons are GOOD reasons to buy Biodiesel, so most boaters surveyed were pretty happy.

Where Boaters Prefer to Buy Biodiesel

Assuming Biodiesel were readily available at convenient marine supply stores and local fuel docks around the SF Bay, boaters were asked where they would prefer to buy the Biodiesel. It should be noted that all of these boaters had already purchased Biodiesel before by driving up to 3 hours (from Santa Cruz or 1-1/2 hours from Sacramento) to buy the product from 1994 through 1997 at CytoCulture's Biodiesel supply station (Biofuel test program) in Richmond. By comparison, today the Biodiesel is available to pump directly into a boat tank at Gas House Cove along the City front of San Francisco (intermittent operation since April 1997) and is presently (October 1997) available at three major stores and 6 fuel docks around the Bay. More are anticipated before the end of the year, as far away as Sacramento and Morro Bay. As for pumping the Biodiesel directly into the boat, there is only one facility (Gas House Cove, San Francisco) available to boaters in Northern California.

Therefore, given the options, the boaters selected multiple places to buy their Biodiesel:

Marine Stores	Fuel Docks (Containers)	SF Fuel Dock (Pumping)
85%	61%	12%

Making Biodiesel more available and convenient for boaters were the most frequently reported suggestions, followed by requests for lowering the price.

The current price for Biodiesel is about $4.95 where ever it is sold now at fuel docks (in containers or pumped) and marine stores around Northern California, so the only incentive left to buy it at one particular facility or another is really just convenience. Finally.

Summary Statements

CytoCulture's survey of 100 boaters using Biodiesel from 1994-1997 has provided the first comprehensive user-derived field data for Marine Biodiesel in the world. Nearly 2,500 gallons of Biodiesel was sold to these boaters, making the average purchase volume for repeat customers about 25 gallons. During this time period, CytoCulture actually moved more than 5,000 gallons of product on an intermittent basis, with long frustrating periods of no Biodiesel when funds were low or regulatory issues were being resolved.

Today, for regulatory and product liability reasons, the Biodiesel is marketed in California strictly as an additive for use in boats at blend ratios up to 20%. It is no longer retailed by CytoCulture as an "experimental biofuel" as it was in the past 4 years. More studies and surveys will be needed to pin down remaining technical and marketing questions.

In general, the recreational boater market appears to be gradually accepting the Biodiesel as a viable diesel fuel additive with distinct benefits (environmental, aesthetic & mechanical) that outweigh the relatively high cost of the product on the West Coast.

Please contact CytoCulture by email at Biodsl@aol.com or by calling 510-233-6660 for more information about this survey and the Marine Biodiesel program in San Francisco. Technical seminar presentations can be arranged for boat shows, yacht clubs and other organizations.